L-406

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SOME EFFECTS OF REYNOLDS AND MACH NUMBERS ON THE LIFT OF AN NACA 0012 RECTANGULAR WING IN THE NACA 19-FOOT PRESSURE TUNNEL

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SOME EFFECTS OF REYNOLDS AND MACH NUMBERS ON THE LIFT OF AN NACA 0012 RECTANGULAR WING IN THE NACA 19-FOOT PRESSURE TUNNEL

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SUMMARY

A short investigation was made in the NACA 19-foot pressure tunnel to determine the aerodynamic characteristics of a rectangular wing model constructed to NACA 0012 airfoil sections. The tests were run with the air in the tunnel at two different pressures: atmospheric (14.7 lb/sq in. abs.) and 35 pounds per square inch absolute. The Reynolds number ranged from 1,070,000 to 5,250,000 for the tests at atmospheric pressure and from 1,960,000 to 8,240,000 for the tests at a pressure of 35 pounds per square inch absolute. The results indicate a marked compressibility effect on the lift coefficients, particularly the maximum lift coefficients, which increase up to a velocity of approximately 150 miles per hour (a Mach number of 0.19) and then decrease rapidly. The results also indicate that, in wind-tunnel testing to determine maximum lift coefficients, compressibility effects may be avoided by limiting the tunnel air-stream test velocity to about 125 miles per hour (a Mach number of 0.17)

INTRODUCTION

During the calibration of the NACA 19-foot pressure tunnel a few years ago, tests were made with a rectangular metal wing constructed to NACA 0012 airfoil sections. The results of these tests, which are reported herein and which have been reported in part as unpublished data of the NACA 19-foot pressure tunnel in references 1 and 2, showed compressibility effects on the lift coefficients that are believed to be of considerable importance in wind-tunnel testing technique as well as in connection with

certain phenomena observed in flight. Inasmuch as the information provided by the present tests is somewhat scanty, further tests are contemplated when the pressure of the present military testing program is relieved.

TESTS AND RESULTS

Figure 1 gives the details of the model. The test setup of the model mounted in the tunnel is shown in figure 2. Force tests were made over an angle-of-attack range from below zero lift through the stall with the air in the tunnel at two pressures, atmospheric (14.7 lb/sq in. abs.) and 35 pounds per square inch absolute. The tests were made at values of dynamic pressure from 10 to 200 pounds per square foot, which gave test Reynolds numbers from 1,070,000 to 5,250,000 at atmospheric pressure and from 1,960,000 to 8,240,000 for 35 pounds per square inch pressure.

Tests were made to determine the effects of support tare and interference, and corrections for these effects were made to the coefficients presented herein. The angles of attack are corrected for jet-boundary effects.

The variation of the lift coefficient C_L with angle of attack α is given in figures 3 and 4 for the tests at the different Reynolds numbers and the two tunnel air-pressure conditions. Examination of these curves reveals some variation of lift-curve slope with Reynolds number. Correcting the slopes to infinite aspect ratio a_0 and plotting a_0 against test Reynolds number (fig. 5) gives a separate curve for each of the two tunnel air pressures. When a_0 is plotted against Mach number, however, the two curves show fair agreement in that the breaks occur at approximately the same Mach number (fig. 5).

In figure 6, the maximum lift coefficient $C_{L_{max}}$ is plotted against test Reynolds number for the two pressure conditions. For atmospheric pressure, the value of $C_{L_{max}}$ increases up to a velocity of approximately 150 miles per hour after which it decreases at a rapid rate for the remaining portion of the range investigated. Increasing the pressure of the air in the tunnel extends the curve obtained at atmospheric pressure to higher values of $C_{L_{max}}$

and to higher values of critical Reynolds number as indicated by the dashed-line curve. The critical Reynolds number in this case also corresponds to a velocity of approximately 150 miles per hour. When these same values of $C_{L_{max}}$ are plotted against Mach number as in figure 7, however, both curves show the peak at approximately the same Mach number (0.19) indicating that the breakdown of the flow is a compressibility effect. A few pressure measurements over the nose of the wing indicate this to be the case. Further detailed pressure measurements are desirable. It should be remembered, however, that both Reynolds and Mach number effects are combined in the results of figures 6 and 7 and that the variation of $C_{L_{max}}$ is due to a combination of these two effects. On the other hand, compressibility effects are quite small for Mach numbers up to 0.17 and variations of $C_{L_{max}}$ below this value therefore are essentially true Reynolds number effects. In reference 2, it has been shown from two-dimensional pressure-distribution tests of airfoils of the NACA 16-series that the curve of $C_{L_{max}}$ against Mach number starts upward again at higher Mach numbers with pronounced increases of maximum lift coefficient being obtained. Unfortunately, it was not possible in the present tests to obtain the high Mach number necessary to show this effect. Further force tests at high Mach numbers appear to be very desirable.

The results of the present investigation of the NACA 0012 wing indicate that tests for the determination of maximum lift coefficient should be made at the Reynolds and Mach numbers corresponding to those existing for the conditions at which the data will be used. Unfortunately, duplication of anticipated conditions of size, altitude, and velocity would be required because the proper Reynolds and Mach numbers can be simultaneously obtained in no other way. Inasmuch as the majority of wind tunnels are dependent upon velocity changes for variation of Mach number, the effects of compressibility and Reynolds number thus obtained cannot be separated; consequently, the Mach number effects at $C_{L_{max}}$ may predominate at much lower than the desired Reynolds number and the data will be misleading. Because the majority of maximum-lift data are applied to the landing and stalling conditions of airplanes in which the velocities are usually less that 125 miles per hour, the compressibility effects are small. For this

reason, it would appear desirable in most cases to make the wind-tunnel tests for maximum lift coefficient at values of Mach number sufficiently low that compressibility effects will be negligible. The present tests indicate that an air-stream velocity of approximately 125 miles per hour (a Mach number of 0.17) would be the upper limit for airfoils with pressure distributions similar to that of the NACA 0012 section. For flight attitudes that require maximum lift at high Mach and Reynolds numbers, such as would be obtained in high-speed turns, however, both the proper Mach and Reynolds numbers should be duplicated.

CONCLUSIONS

From the tests of an NACA 0012 rectangular wing in the NACA 19-foot pressure tunnel herein reported, the following conclusions may be drawn:

1. Compressibility effects produce pronounced changes in the value of the maximum lift coefficient for Mach numbers exceeding approximately 0.17. Below this value, Reynolds number effects apparently predominate.

2. Determination of the maximum lift coefficient by wind-tunnel tests must therefore be done with due regard for the flight condition to which the results will be applied.

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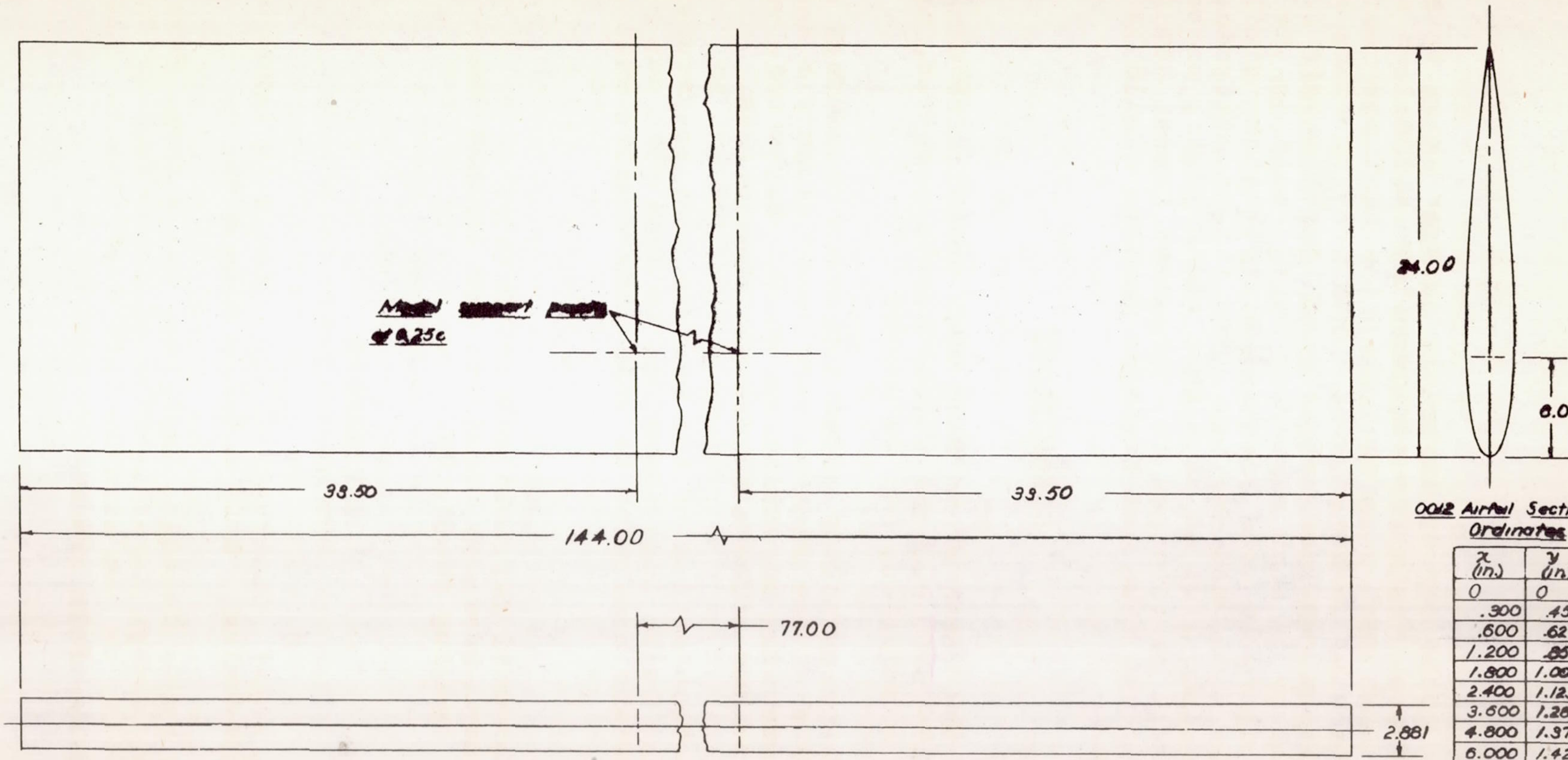
REFERENCES

1. Stack, John: Compressibility Effects in Aeronautical Engineering. NACA A.C.R., Aug. 1941.

2. Stack, John, Fedziuk, Henry A., and Cleary, Harold E.: Preliminary Investigation of the Effect of Compressibility on the Maximum Lift Coefficient. NACA A.C.R., Feb. 1943.

L-406



All dimensions in inches

0012 Airfoil Section Ordinates

x (in.)	y (in.)
0	0
.300	.4546
.600	.6276
1.200	.8532
1.800	1.0080
2.400	1.1239
3.600	1.2828
4.800	1.3771
6.000	1.4258
7.200	1.4405
9.600	1.3927
12.000	1.2706
14.400	1.0951
16.800	.8794
19.200	.6295
21.600	.3475
22.800	.1937
24.000	.0302
L.E. Rad.=.3792	

Figure 1.- General dimensions of all-metal rectangular NACA 0012 wing.

L-406

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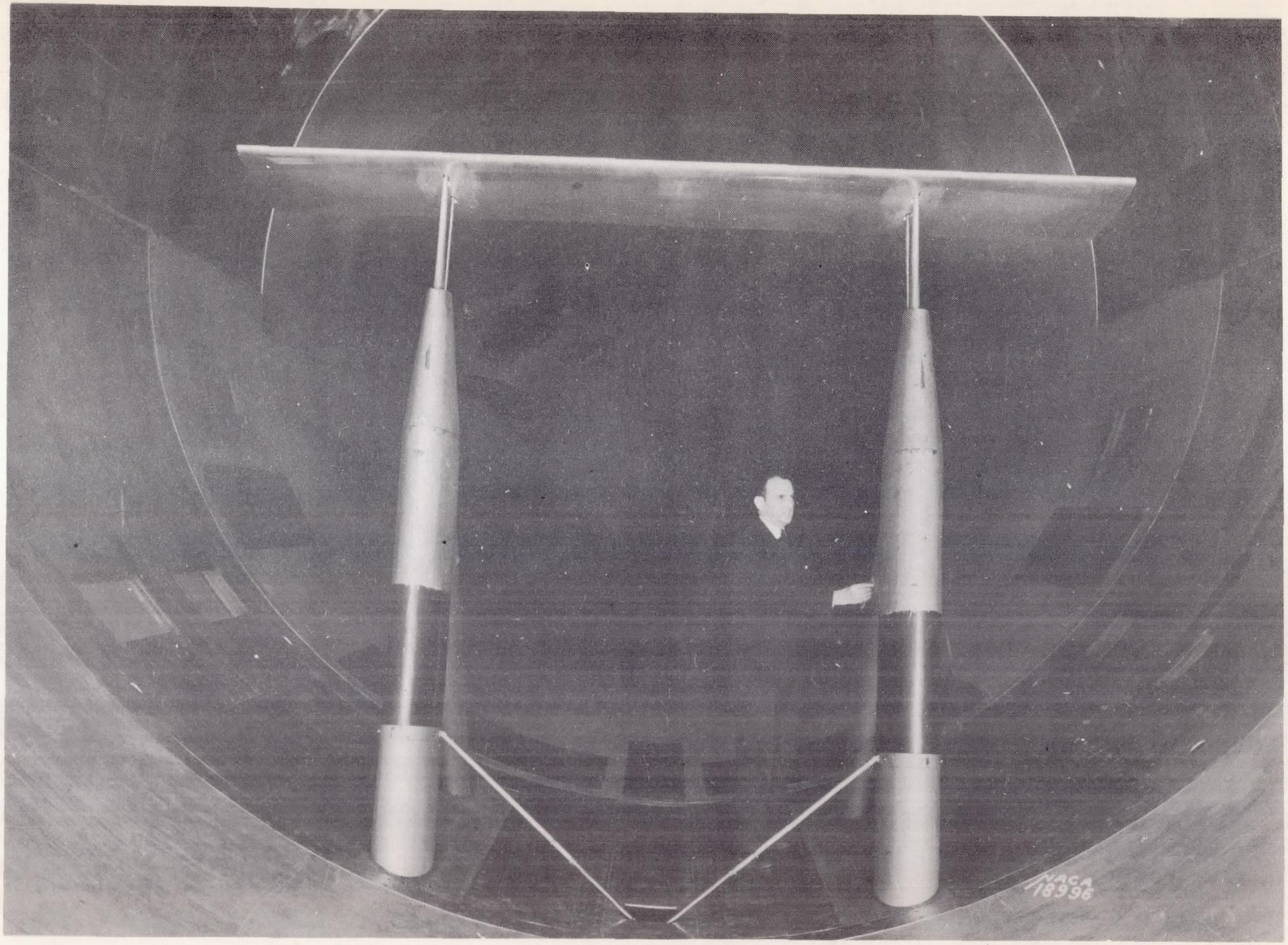

Fig. 2

Figure 2.- Rectangular NACA 0012 airfoil model mounted on the normal supports in the NACA 19-foot pressure tunnel.

L-406

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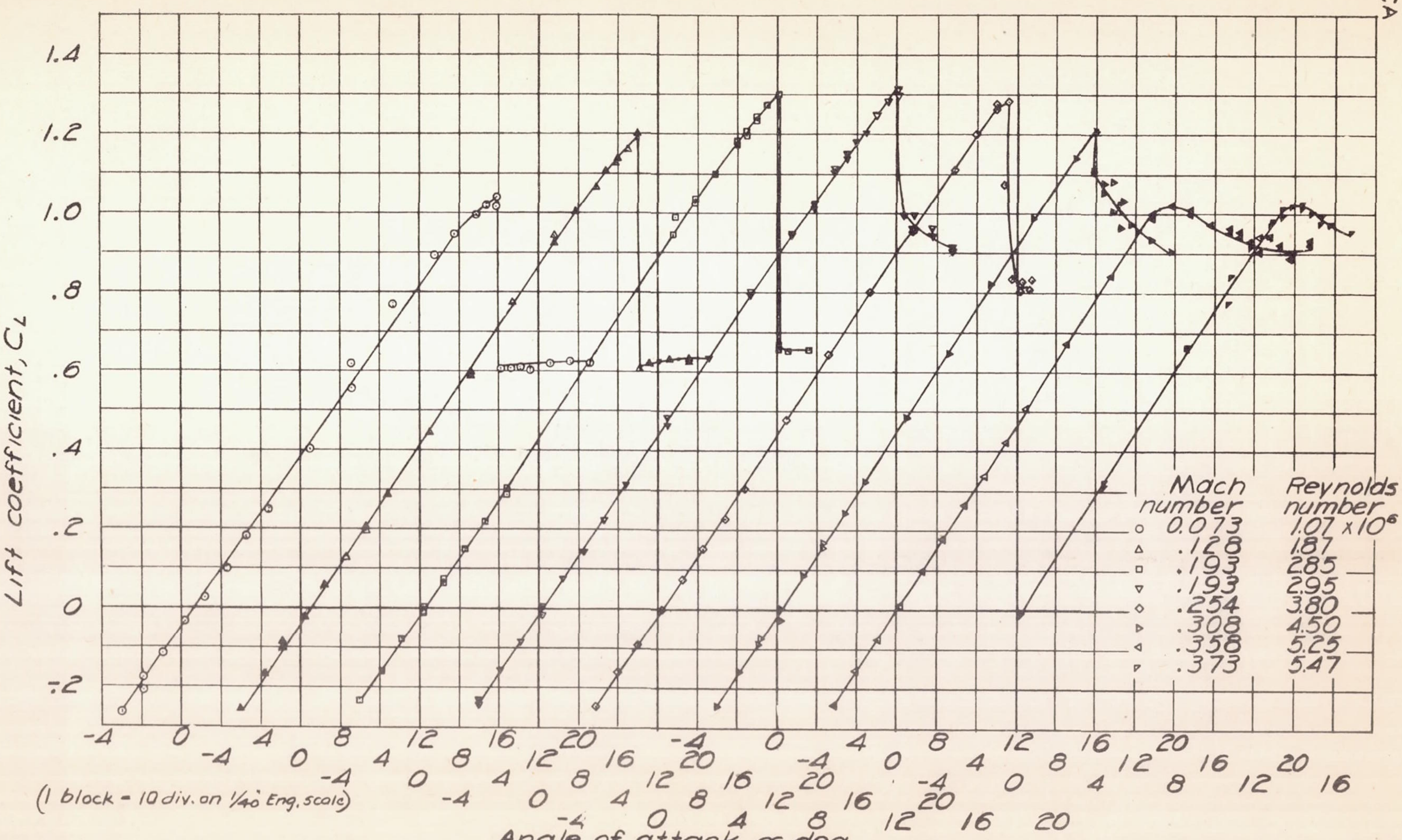

Figure 3.-Variation of lift coefficient with angle of attack for NACA 0012 rectangular wing. Pressure, 14.7 pounds per square inch absolute.

Fig. 3

L-406

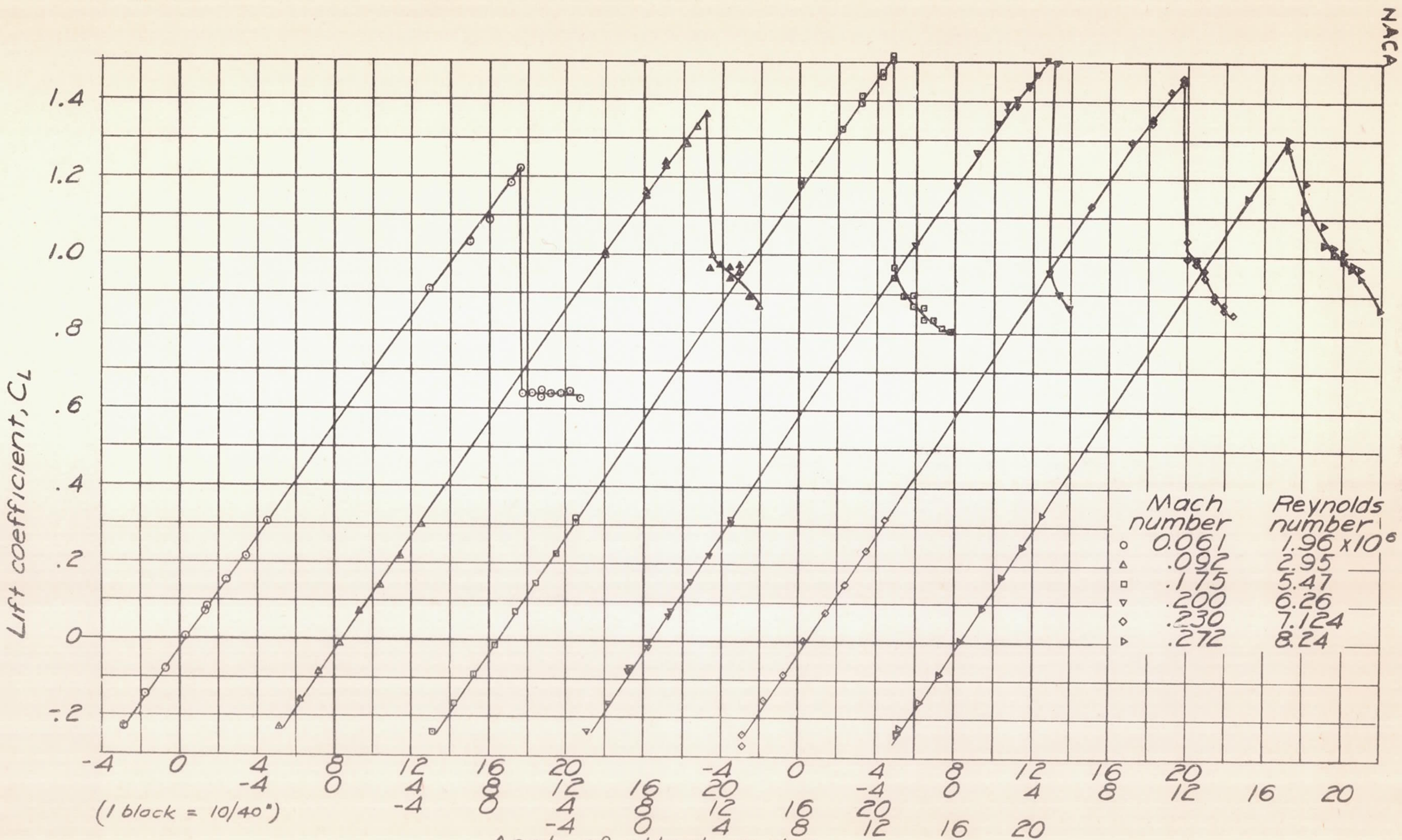

Figure 4.-Variation of lift coefficient with angle of attack for NACA 0012 rectangular wing. Pressure, 35 pounds per square inch absolute.

Fig. 4

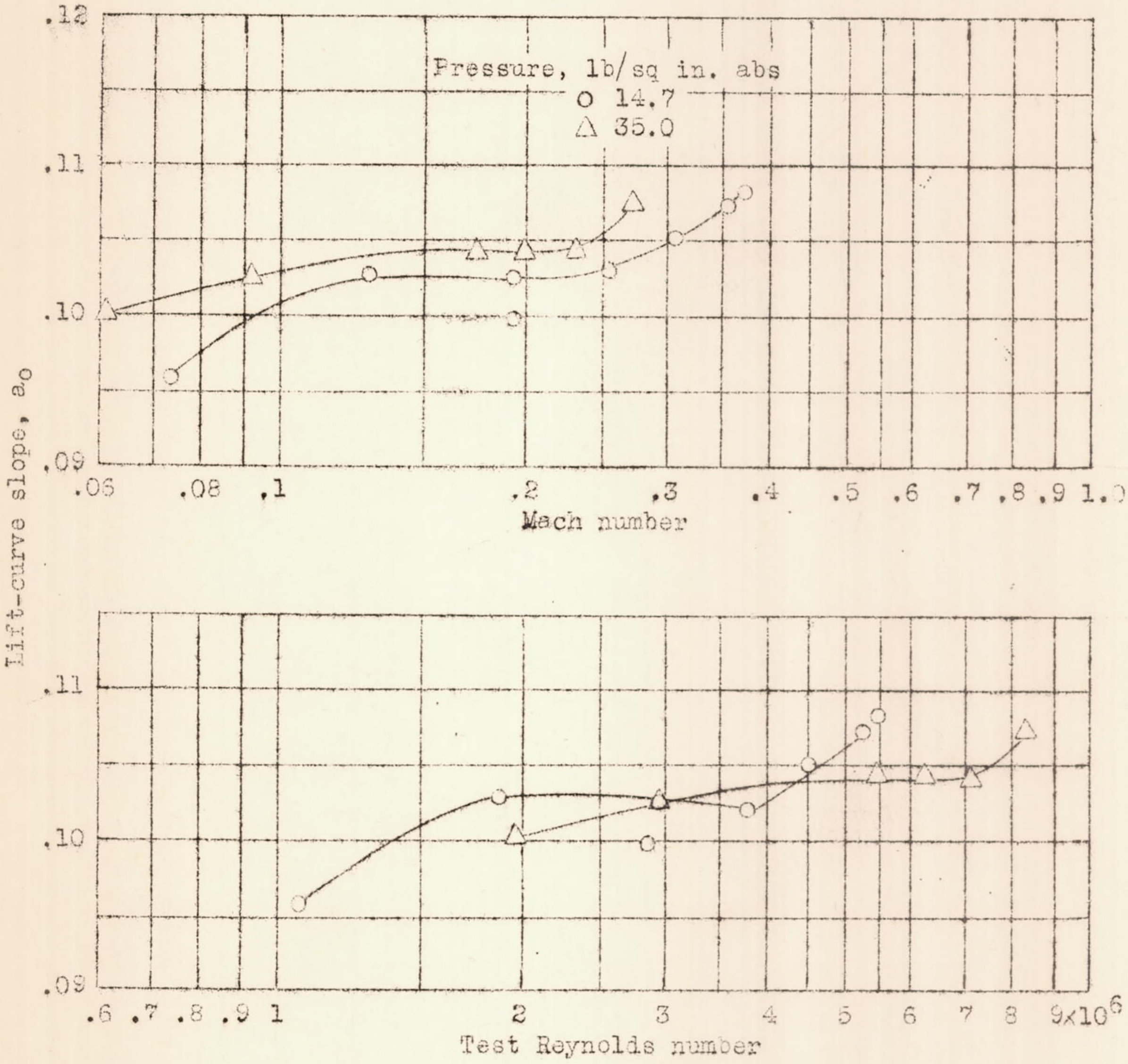

Figure 5.- Variation of lift-coefficient-curve slope with test Reynolds number and Mach number for NACA 0012 rectangular wing.

L-406

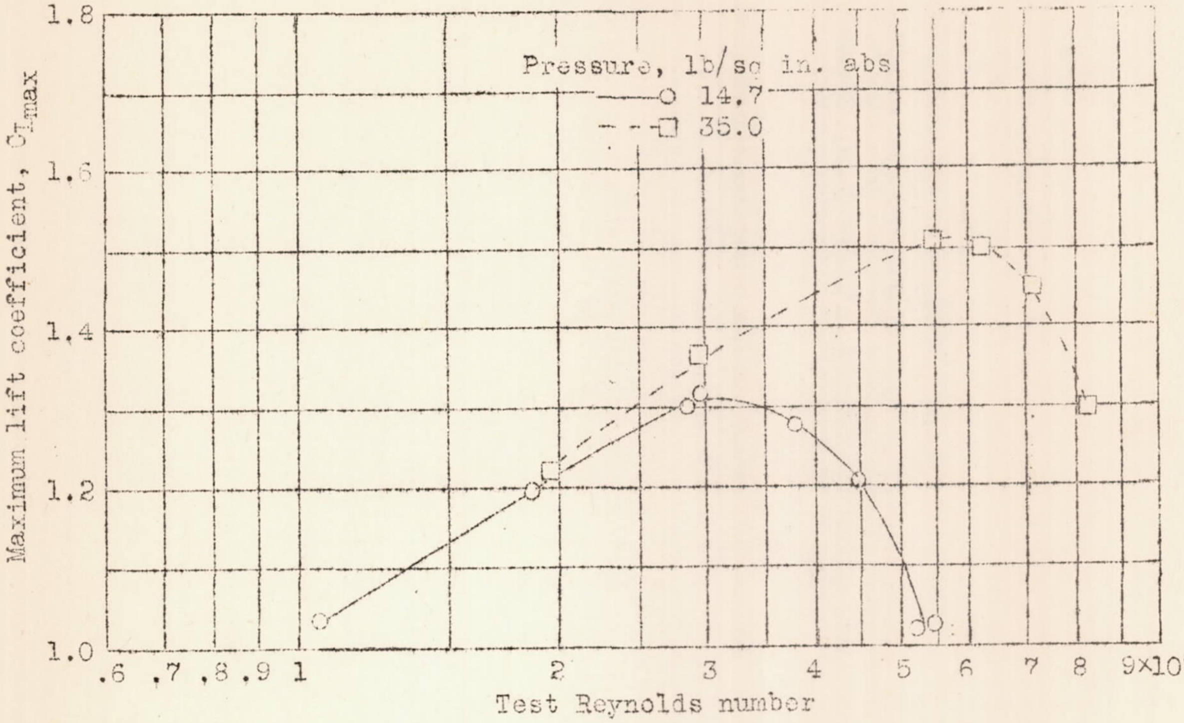

Figure 6.- Variation of maximum lift coefficient with test Reynolds number for NACA 0012 rectangular wing.

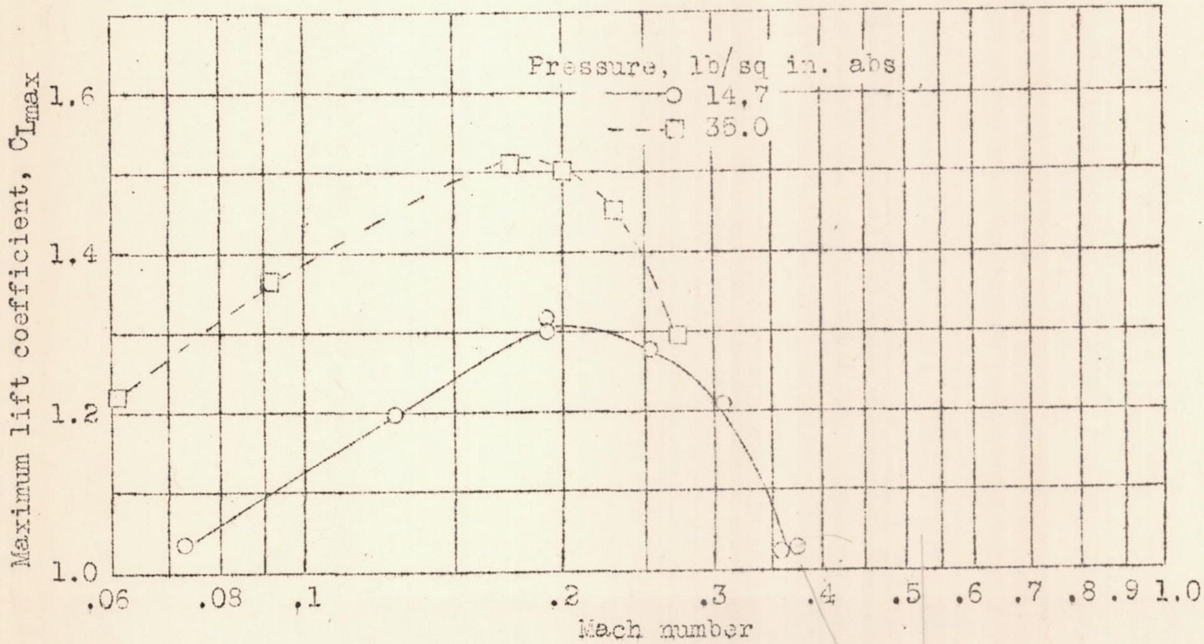

Figure 7.- Variation of maximum lift coefficient with Mach number for NACA 0012 rectangular wing.

$C_{L_{max}}$ 7